

# Supersymmetry and Superpartners

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**Abstract.** A brief summary is given of studies on supersymmetry and the spectrum of superparticles presented at the Linear Collider Workshop 2000.

## I INTRODUCTION

Although the Standard Model (SM) is extremely successful, many physicist believe that new physics will show up at the TeV scale. Supersymmetry (SUSY) is considered as the most attractive extension of the Standard Model, in particular in its variant of the Minimal Supersymmetric Standard Model (MSSM). The open question of how supersymmetry is broken and how this breaking is communicated to the particles has been discussed by Godbole [1]. Frequently used schemes are the minimal supergravity (mSUGRA) model, gauge mediated (GMSB), gaugino mediated ( $\chi$ MSB) and anomaly mediated (AMSB) supersymmetry breaking models, which all lead to quite different phenomenological implications. In many scenarios at least some particles of the supersymmetric spectrum — especially the non-coloured charginos, neutralinos and sleptons — are expected to be light enough to be accessible at one of the proposed  $e^+e^-$  Linear Colliders operating at  $\sqrt{s} = 0.5 - 1$  TeV.

Since the last workshop of this series, LCWS 99 [2], some ongoing studies on supersymmetry and the superpartners of the SM particles have been completed and many new ideas have been addressed.

A major concern is, what collider energy is required? Cosmological constraints have been discussed by Feng [3]. If the lightest neutralino  $\tilde{\chi}_1^0$  is taken as cold dark matter candidate in mSUGRA models, cosmology does not provide useful bounds on superpartner masses. A possibly large scalar mass  $m_0 \gtrsim 1$  TeV would lead to heavy sleptons without affecting the low mass gaugino sector. But if SUSY should be observable at 500 GeV, then some signature of supersymmetry should already show up before the LHC, which would be very exciting.

Arguments of naturalness and fine tuning were examined by Anderson [4]. He comes to the conclusion that if supersymmetry is relevant to the weak scale, it should provide a multitude of sparticles, but probably not the complete spectrum, kinematically accessible at a 1 TeV Linear Collider.

Murayama [5] pointed out that in order to establish SUSY and to remove ambiguous interpretations by alternative theories, as many observables of the sparticle spectrum as possible have to be measured and proven to be consistent with supersymmetry. Each SM particle has to have a superpartner with a spin differing by 1/2, the same gauge quantum numbers and identical couplings, for example  $g_{e\nu W} = g_{e\tilde{\nu}\tilde{W}}$ . This will be a long-term programme and the required precision can only be achieved at an  $e^+e^-$  Linear Collider.

## II POLARISATION

A very important tool to study supersymmetry will be the use of highly polarised beams, as discussed by Moortgat-Pick [6]. Performances of  $\mathcal{P}_{e^-} = 0.8$  and  $\mathcal{P}_{e^+} = 0.6$  appear feasible. A proper choice of polarisations and centre of mass energy helps disentangle the particle spectrum by enhancing specific reactions and suppressing unwanted background. Electron polarisation is absolutely essential to determine the weak quantum numbers, couplings and mixings, *e.g.* to associate the chiral couplings of the right-handed and left-handed fermions to their  $R$ ,  $L$  superpartners. Positron polarisation offers additional important advantages by selecting respectively enriching initial states of a definite spin: (i) it provides an improved separation of sparticle production and decay topologies and thus a higher precision on model parameters by exploiting all combinations of polarisations; (ii) it increases the event rate (factor 1.5 or more) resulting in a higher sensitivity to rare decays and subtle effects; and (iii) it strongly supports the discovery of new physics, *e.g.* the exchange of spin 0 particles. Note that all types of helicity conserving processes (SM and alternative theories) profit in increased rates by having both  $e^\pm$  beams polarised. A few examples should illustrate the impact of positron polarisation.

▷ An interesting case is associated selectron production  $e^-e^+ \rightarrow \tilde{e}_R\tilde{e}_L$  via  $t$  channel  $\tilde{\chi}^0$  exchange. Using polarised beams the charge of the observed lepton can be directly related to the  $L$ ,  $R$  quantum number of the produced selectron,  $e_{L,R}^- \rightarrow \tilde{e}_{L,R}^-$  and  $e_{L,R}^+ \rightarrow \tilde{e}_{L,R}^+$  at the corresponding vertex. This elegant separation of selectron species and their decay spectra has been proposed for polarised electrons in the talk by Dima [7]. But obviously the method can be efficiently improved if the  $e^+$  beam is polarised as well.

▷ Stop quarks are expected to have large mixings between  $\tilde{t}_L$  and  $\tilde{t}_R$ , *e.g.* the lighter state being  $\tilde{t}_1 = \tilde{t}_L \cos \theta_{\tilde{t}} + \tilde{t}_R \sin \theta_{\tilde{t}}$ . The polarised cross sections  $e_L^+e_R^- \rightarrow \tilde{t}_1\tilde{t}_1$  and  $e_R^+e_L^- \rightarrow \tilde{t}_1\tilde{t}_1$  have a characteristic dependence on the mass and stop mixing angle  $\theta_{\tilde{t}}$ . A simulation of stop decays  $\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$ ,  $b\tilde{\chi}_1^+$  shows that the sensitivity to both parameters can be increased by more than 20 % when choosing the maximal  $e^-$  and  $e^+$  polarisation, see contribution of Sopczak [8].

▷ Gaugino production  $e^+e^- \rightarrow \tilde{\chi}_i^+\tilde{\chi}_j^-$ ,  $\tilde{\chi}_i^0\tilde{\chi}_j^0$  exhibit a very pronounced polarisation dependence. With polarised positrons the error on SUSY parameters and the masses of exchanged sleptons can be substantially reduced. In particular the reach and separation towards extended models with low cross sections, such as NMSSM

and E6, can be largely extended [6].

▷ Very spectacular signatures would arise from rare processes with ‘wrong’ helicities, which are absent in the Standard Model. Such reactions may occur through spin 0 sparticle exchange in  $R_p$  violating SUSY models. Examples are resonant or contact interaction type fermion pair production  $e^+e^- \rightarrow \tilde{\nu} \rightarrow \ell\bar{\ell}$  and single neutralino or chargino production  $e^+e^- \rightarrow \tilde{\nu} \rightarrow \nu\tilde{\chi}^0, \ell^\pm\chi^\mp$  mediated through  $s$ -channel sneutrino exchange.

### III SLEPTONS

Scalar leptons are the superpartners of the right-handed and left-handed leptons. They are produced in pairs

$$\begin{aligned} e^+e^- &\rightarrow \tilde{e}_R\tilde{e}_R, \tilde{e}_L\tilde{e}_L, \tilde{e}_R\tilde{e}_L, \tilde{\nu}_e\tilde{\nu}_e \\ e^+e^- &\rightarrow \tilde{\mu}_R\tilde{\mu}_R, \tilde{\mu}_L\tilde{\mu}_L, \tilde{\nu}_\mu\tilde{\nu}_\mu \\ e^+e^- &\rightarrow \tilde{\tau}_1\tilde{\tau}_1, \tilde{\tau}_2\tilde{\tau}_2, \tilde{\tau}_1\tilde{\tau}_2, \tilde{\nu}_\tau\tilde{\nu}_\tau \end{aligned}$$

via  $s$ -channel  $\gamma/Z$  exchange. In addition the  $t$ -channel contributes in selectron production via neutralinos and in electron-sneutrino production via charginos. The decays  $\tilde{\ell}^- \rightarrow \ell^- \tilde{\chi}_i^0$  and  $\tilde{\nu}_\ell \rightarrow \ell^- \tilde{\chi}_i^+$  allow a clean identification and accurate measurements of the primary and secondary sparticle masses and other slepton properties like spin, branching ratios, couplings and mixing parameters, see *e.g.* reports at LCWS 99 [2].

The masses of the first and second generation of sleptons can be determined within a few per mil from the isotropic two-body decay kinematics and to the order of 100 MeV from cross section measurements,  $\sigma_{\tilde{\ell}\bar{\ell}} \sim \beta^3$ , at threshold.

It has been suggested that  $e^-e^-$  collisions provide a clean environment to study selectron production [9]. The main interest lies in mass determinations through threshold scans. Selectrons associated to the same fermion helicity,  $e^-e^- \rightarrow \tilde{e}_R\tilde{e}_R, \tilde{e}_L\tilde{e}_L$ , have a large cross section rising as  $\sigma \sim \beta$ , in contrast to  $e^+e^-$  annihilation. A simulation using the NLC machine parameters was presented by Heusch [10] and shows, however, that this apparent advantage is depleted by initial state radiation and beamstrahlung effects. The excitation curve is severely degraded and looks in shape (flattening of the steep rise) and magnitude very similar to the  $e^+e^- \rightarrow \tilde{e}^+\tilde{e}^-$  case. Given the considerably lower luminosity, factor of  $\sim 1/5$ , it is questionable whether a competitive or even more precise mass measurement will be achievable in comparable running times.

Studies of the third slepton generation,  $\tilde{\tau}$  and  $\tilde{\nu}_\tau$ , have been presented by Mizukoshi [11]. Due to large Yukawa couplings the stau physical eigenstates are mixed,  $\tilde{\tau}_1 = \tilde{\tau}_L \cos \theta_{\tilde{\tau}} + \tilde{\tau}_R \sin \theta_{\tilde{\tau}}$  and  $\tilde{\tau}_2 = \tilde{\tau}_R \cos \theta_{\tilde{\tau}} - \tilde{\tau}_L \sin \theta_{\tilde{\tau}}$ , and are no longer degenerate with the selectron and smuon masses. While identification via decays  $\tilde{\tau}_1 \rightarrow \tau \tilde{\chi}_1^0$  will be easy and efficient, the background is large ( $W^+W^-$  and other SUSY production) and a mass determination using the spectra of  $\tau$  decays is

much less accurate. The mixing angle  $\theta_{\tilde{\tau}}$  can be accessed through  $\tau$  polarisation  $\mathcal{P}_{\tau} = \sin\theta_{\tilde{\tau}}^2 - \cos\theta_{\tilde{\tau}}^2$  which is measurable via the distinct energy spectra of the decays  $\tau \rightarrow \pi\nu, \rho\nu$ . An accuracy of 10% with  $\mathcal{L} = 50 \text{ fb}^{-1}$  can be achieved. Such a polarisation study has been applied to decays  $\tilde{\tau} \rightarrow \tau\tilde{G}$  in a GMSB model, where the gravitino  $\tilde{G}$  is the lightest sparticle. It allows to test the coupling  $\tau\tilde{\tau}\tilde{G}$  and to set limits on the stau lifetime in this model.

Recent results from Super-Kamiokande [12] suggest that neutrinos oscillate ( $\nu_{\mu} - \nu_{\tau}$ ) and thus are massive. As a consequence there should also exist the superpartners  $\tilde{\nu}_R$  of right-handed neutrinos (RHN). The addition of a new singlet neutrino field would change the predictions for slepton masses [11]. RHN effects may be observable as deviations from mass relations, in particular those involving the third generation, *e.g.*  $2(m_{\tilde{\nu}_R}^2 - m_{\tilde{\nu}_{\tau}}^2) \approx m_{\tilde{e}_R}^2 - m_{\tilde{\tau}_1}^2$  (up to higher order corrections). In order to become observable, present data require a sensitivity on mass measurements of 2.5%. The limitation comes from the third slepton generation. In a case study  $m_{\tilde{\tau}_1}$  could be determined to 1.5% using hadronic  $\tau$  decay spectra, while the accuracy for  $m_{\tilde{\nu}_{\tau}}$  obtained from cross section measurements well above threshold is much worse and insufficient and needs to be improved.

## IV CHARGINOS AND NEUTRALINOS

Charginos and neutralinos are produced in pairs

$$\begin{aligned} e^+e^- &\rightarrow \tilde{\chi}_i^+ \tilde{\chi}_j^- & [i, j = 1, 2] \\ e^+e^- &\rightarrow \tilde{\chi}_i^0 \tilde{\chi}_j^0 & [i, j = 1, \dots, 4] \end{aligned}$$

via  $s$ -channel  $\gamma/Z$  exchange and  $t$ -channel selectron or sneutrino exchange. They are easy to detect via their decays into lighter charginos/neutralinos and gauge or Higgs bosons or into sfermion-fermion pairs. If these two-body decays are kinematically not possible, typically for the lighter chargino and neutralino, they decay via virtual gauge bosons and sfermions, *e.g.*  $\tilde{\chi}_1^+ \rightarrow f\bar{f}'\tilde{\chi}_1^0$  or  $\tilde{\chi}_2^0 \rightarrow f\bar{f}\tilde{\chi}_1^0$ . In  $R$ -parity conserving MSSM scenarios the lightest neutralino  $\tilde{\chi}_1^0$  is stable. Typical mass resolutions (see *e.g.* contributions to [2]) for the lighter chargino and neutralinos are expected to be at the per mil level from decays into electrons, muons or quark jets and below 100 MeV from threshold scans, where the cross section rises as  $\sigma_{\tilde{\chi}\tilde{\chi}} \sim \beta$ . Charged and neutral  $\tilde{\chi}$ 's are abundantly produced in decay chains of heavy SUSY particles. By exploiting all di-lepton and di-jet mass spectra one will be able to measure mass difference of cascade decays, *e.g.*  $\Delta m(\tilde{\chi}_2^0 - \tilde{\chi}_1^0)$  and  $\Delta m(\tilde{\chi}_1^{\pm} - \tilde{\chi}_1^0)$ , with a resolution of better than 50 MeV, essentially given by the detector performance.

For large  $\tan\beta$  the decay pattern may be very different and the mass splitting of the  $\tilde{\tau}$  sector may lead to a situation where  $m_{\tilde{\tau}_1} < m_{\tilde{\chi}_1^{\pm}}, m_{\tilde{\chi}_2^0}$ . Consequently the decays  $\tilde{\chi}_1^+ \rightarrow \tilde{\tau}_1^+ \nu$  and  $\tilde{\chi}_2^0 \rightarrow \tilde{\tau}_1^+ \tau^-$  dominate over all other decay modes via lepton or quark pairs. A simulation of  $e^+e^- \rightarrow \tilde{\chi}_1^+ \tilde{\chi}_1^- \rightarrow \tilde{\tau}_1^+ \nu \tilde{\tau}_1^- \nu \rightarrow \tau^+ \nu \tilde{\chi}_1^0 \tau^- \nu \tilde{\chi}_1^0$  with

$m_{\tilde{\chi}_1^\pm} = 172.5$  GeV,  $m_{\tilde{\tau}_1} = 152.7$  GeV,  $m_{\tilde{\chi}_1^0} = 86.8$  GeV and  $\tan\beta = 50$  was reported by Kamon [13]. Fitting the energy distribution of hadronic  $\tau$  decays, which depend on the masses of all three sparticles involved, results in resolutions of about 4% for the  $\tilde{\chi}_1^\pm$  and  $\tilde{\tau}_1$  masses. Note that cross section measurements are less affected by  $\tau$  topologies and become more important for precise mass determinations in large  $\tan\beta$  scenarios.

The properties of the chargino and neutralino systems and the extraction of fundamental SUSY parameters in a model independent way have been discussed by Kalinowski [14] and Blöchliger [15]. In the MSSM the chargino system depends on the parameters  $M_2$ ,  $\mu$  and  $\tan\beta$ . Charginos are composed of Winos and Higgsinos. An easy way to access the Wino component is via  $t$ -channel  $\tilde{\nu}_e$  exchange, which couples only to left-handed electrons. Thus the mixing parameters of the chargino system as well as the mass of the exchanged sneutrino can be determined by varying the beam polarisation. If the collider energy is sufficient to produce all chargino states the SUSY parameters can be extracted from the masses and polarised production cross sections in an unambiguous way. The neutralino system, which is a mixture of Bino, Wino and two Higgsino fields, depends in addition to  $M_2$ ,  $\mu$  and  $\tan\beta$  on the  $U(1)$  gaugino parameter  $M_1$ . The diagonalisation of the  $4 \times 4$  mass matrix is much more involved and a general analysis to extract the four fundamental SUSY parameters has not yet been done. Therefore the neutralinos are primarily used to determine  $M_1$  [15]. Further, if not directly accessible, the mass of the exchanged selectron can be determined up to 800 GeV with a resolution of 10 GeV. It should be noted once more that the use of polarisation as well as exploiting spin correlations, for instance in the reaction  $e^+e^- \rightarrow \tilde{\chi}_2^0\tilde{\chi}_1^0 \rightarrow \ell^+\ell^-\tilde{\chi}_1^0\tilde{\chi}_1^0$ , is of great importance.

For final precision measurements the inclusion of higher order electroweak radiative corrections will be important, as discussed by Díaz [16]. They may change the polarised cross sections by up to 15% and also have a strong influence on the scheme dependent definitions of masses. The expected sensitivity of the chargino and neutralino systems to the parameters of two mSUGRA models are given in table 1.  $M_1$ ,  $M_2$  and  $\mu$  can be determined very precisely to one per cent or bet-

**TABLE 1.** Estimated accuracy for the parameters  $M_2$ ,  $\mu$  and  $\tan\beta$  from chargino and  $M_1$  from neutralino production for mSUGRA scenarios (based on  $\mathcal{L} = 500 \text{ fb}^{-1}$  for each  $e^-$  polarisation)

parameter	input	fit value	input	fit value
$M_2$	152 GeV	$152 \pm 1.8$ GeV	150 GeV	$150 \pm 1.2$ GeV
$\mu$	316 GeV	$316 \pm 0.9$ GeV	263 GeV	$263 \pm 0.7$ GeV
$\tan\beta$	3	$3 \pm 0.7$	30	$> 20$
$M_1$	78.7 GeV	$78.7 \pm 0.7$ GeV	78.0 GeV	$78.0 \pm 0.4$ GeV

ter. Large  $\tan\beta$  values are difficult to extract from the  $\chi$  systems, they are easier

accessible in the  $\tilde{\tau}$  sector.

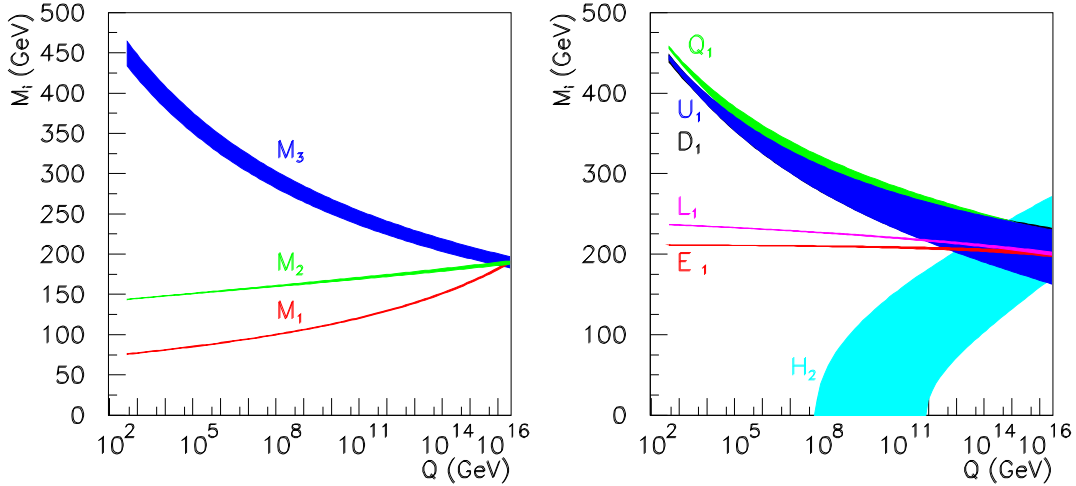
In general, the parameters  $M_1$ ,  $M_2$  and  $\mu$  can be complex, which also leads to  $CP$  violation. In fact,  $M_2$  may be taken real, so that only two additional phases  $\phi_\mu$  and  $\phi_{M_1}$  remain. The detection of  $CP$  violating phases in MSSM models has been discussed by Plehn [17]. Limits from the electric dipole moments of the electron, neutron and mercury suggest small phases of  $\phi \lesssim 0.001$ . Measurements of chargino and neutralino masses and production cross sections would only give a modest precision of  $\delta\phi \simeq 0.1$ . A more promising approach is to construct directly  $CP$  sensitive quantities, like triple products of momentum vectors. Consider for example the reaction  $e^+e^- \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_1^0 \rightarrow e^+e^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$ . The distribution of the angle between the normal of the di-lepton plane and the beam direction is expected to exhibit  $CP$  asymmetries of typically 0.1 – 1.5%, which is a challenge to the experiments.

A quite different  $\tilde{\chi}$  (and  $\tilde{\ell}$ ) mass spectrum is predicted in so-called anomaly mediated SUSY breaking (AMSB) models, where gaugino masses are no more universal but generated at one loop. The reversed hierarchy of gaugino parameters  $M_1 \sim 3 M_2$  (in contrast to SUGRA with  $M_1 \simeq 0.5 M_2$ ) leads to near degeneracy of the lighter chargino  $\tilde{\chi}_1^\pm$  and the wino-like neutralino  $\tilde{\chi}_1^0$  masses. Search strategies for  $e^+e^- \rightarrow \tilde{\chi}_1^+ \tilde{\chi}_1^-$  production in AMSB models were discussed by Mrenna [18]. The signatures rely on the lifetime and decay modes of  $\tilde{\chi}_1^\pm$ , which depend almost entirely on the small mass difference  $\Delta m_{\tilde{\chi}_1} \equiv m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0}$ . If  $\Delta m_{\tilde{\chi}_1} < 0.2$  GeV the chargino has a long lifetime yielding either a heavily ionising or a terminating track without visible decay products. For  $0.2 \text{ GeV} < \Delta m_{\tilde{\chi}_1} \lesssim 2 \text{ GeV}$ , most typical of models with loop-dominated gaugino masses, the decay pion(s) will be detected, possibly associated to a secondary vertex. The large  $\gamma\gamma \rightarrow \pi\pi$  background may be suppressed by requiring an additional photon. If the pions have too low an energy to be detected, then one relies on a single photon plus missing mass from  $e^+e^- \rightarrow \gamma \tilde{\chi}_1^+ \tilde{\chi}_1^-$ . Once  $\Delta m_{\tilde{\chi}_1} \gtrsim 2 \text{ GeV}$ , the  $\tilde{\chi}^\pm$  signatures resemble the usual MSSM topologies. With a luminosity of  $\mathcal{L} = 50 \text{ fb}^{-1}$  the AMSB discovery potential extends over a large  $\Delta m_{\tilde{\chi}_1}$  region almost to the kinematic limit.

## V SUSY PARAMETERS AT HIGH ENERGY SCALES

The precise mass measurements of sleptons, neutralinos and charginos constitute an over-constrained set of observables, which allow the structure and parameters of the underlying SUSY theory to be determined. The renormalisation group equations (RGE) relate the observable masses to the fundamental SUSY parameters at high energy scales. Two different approaches were discussed by Blair [19].

A widely used strategy, for example at the LHC, is to assume a SUSY breaking scenario and then fit to the corresponding low-energy particle spectrum including experimental uncertainties. If applying such a model dependent top-down approach to a specific mSUGRA model one expects excellent accuracies for the parameters: for the common scalar mass  $m_0 = 100 \pm 0.09 \text{ GeV}$ , for the common gaugino mass



**FIGURE 1.** Evolution of gaugino and sfermion mass parameters in a mSUGRA scenario for  $m_0 = 200$  GeV,  $m_{1/2} = 190$  GeV,  $A_0 = 500$  GeV,  $\tan\beta = 30$  and  $\text{sign}\mu < 0$ . The bands indicate 95% CL contours.

$m_{1/2} = 200 \pm 0.10$  GeV,  $\tan\beta = 3 \pm 0.02$  and for the trilinear coupling  $A_0 = 0 \pm 6.3$  GeV. The magnitude of  $\mu$  is obtained implicitly by the requirement of electroweak symmetry breaking. The weakness of such an approach is that scenario assumptions are effectively constraints in the fit and so one may miss alternative solutions or new intermediate scales below the GUT scale.

The great advantage of an  $e^+e^-$  Linear Collider is that the rich and precise information allows to perform a model independent analysis, where the structure of the theory is extrapolated from low energy to high energy scales via RGEs. Input to this bottom-up approach are experimental measurements alone without any assumption on a model. An extrapolation of SUSY parameters from the weak scale to the GUT scale within a mSUGRA scenario is shown in figure 1. The gaugino mass parameters  $M_{1,2,3}$  and the slepton mass parameters  $M_{L_1}, M_{E_1}$  for the first and second generation are in excellent agreement with unification. Using only LHC information would give uncertainties on the unification scale worse by more than an order of magnitude. The squark parameters  $M_{Q_1}, M_{U_1}, M_{D_1}$  and the Higgs parameter  $M_{H_2}$ , being less well known, still allow to test unification. New patterns at intermediate scales would be immediately visible.

## VI OUTLOOK

The present Linear Collider projects JLC, NLC and TESLA will probably not be able to explore the full supersymmetry spectrum. A multi-TeV collider may be necessary to complete the programme, in particular to study the properties of the coloured squarks and gluinos. A first look on experimentation at CLIC has been taken by Wilson [20]. A case study to search for di-leptons from SUSY processes

around 3 TeV shows that edges in energy spectra from decay kinematics are difficult to observe due to more degenerate mass spectra as well as detector and machine effects. ISR and beamstrahlung effects provide a relatively wide energy spread; but mass determinations of a couple of per cent from threshold scans should be feasible. The search strategy would probably be a bottom-up approach and slowly rise the cms energy above each sparticle threshold and make use of polarisation to improve on the signal.

If supersymmetry is realised at low energy, an  $e^+e^-$  Linear Collider will be an ideal instrument to explore the full portrait of the accessible sparticle spectrum. This workshop has shown that much progress has been made to develop the tools — experimental analysis techniques and theoretical ideas — to determine the sparticle properties with high accuracy. The LHC may discover supersymmetry and constrain its gross features. However, only high precision measurements at the Linear Collider will be able to pin down the detailed structure of the underlying supersymmetry theory. The potential of the Linear Collider includes specifically:

- precise determination of sparticle masses, widths and branching ratios
- precise determination of couplings
- measurement of mixing angles in the  $\tilde{t}$  and  $\tilde{\tau}$  sectors
- determination of large  $\tan\beta$  in the  $\tilde{\tau}$  sector
- determination of spin-parity  $J^{PC}$  and electroweak quantum numbers
- model independent determination of SUSY parameters

It should be emphasised once more that for this ambitious programme the highest possible luminosity is required and the availability of polarised beams is important.

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